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LAW OF GROWTH IN FORECASTING DEMAND

By Raymond B. Prescott

A number of years ago in plotting the growth of the population in the United States as a whole, and also in several of the older states of the Union, I found that they all traced a similar curve. While reading Tarde's *Laws of Imitation* I noticed that he mentioned a similar curve for the growth of railroads and of tobacco consumption in France. This led me to plot the growth of several products in the United States. Again I found a similar curve. I noted also that all the data plotted were of products that were a direct function of population. These results seemed to indicate that there is a general law of growth that would fit the growth of population, and also some products, perhaps all, that are a direct function of the growth of population.

The curve seems to pass through four phases, indicating that population and industry perhaps pass through the same phases or periods in the course of their development. An investigation of the growth of several industries seemed further to confirm this idea. The four stages seemed to be[1]:

(1) Period of experimentation.

(2) Period of growth into the social fabric.

(3) Through the point where the growth increases but at a diminishing rate.

(4) Period of stability.

If this growth is fundamental and common for all industries whose products are a direct function of the growth of population, and if this growth could be expressed by a general type of equation, it is not difficult to conceive that when one part of the growth is known the others can be determined. To explain past performances and predict the future are not different operations. They are the same operations working in opposite directions, one from effect to cause and the other from cause to effect.

During the period of experimentation the permanent success of an industry is doubtful because man, being a creature of habit, dislikes to have his routine changed. He accepts very slowly anything that tends to alter his course from its accustomed path; consequently he opposes the object that is tending to vary his usual habits. The success of the industry depends upon how well the resisting habits of man are overcome. Some individuals are more easily overcome than others, and soon become part of the force working to overcome the general resistance.

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[1] I am indebted to Mr. Harry Tipper, of *Automotive Industries*, for aid in defining the four stages.

If the industry succeeds in overcoming man's natural resistance to having his habits disturbed, then progress of the industry enters into the period of growth into the social fabric, where it either becomes a part of the daily life of man or fails. Rate of growth varies with every industry, the rate depending upon the industry's adaptability to the economic and social life of man, which in turn depends upon the characteristics of the product and the incentive for its use created by man himself.

During the course of its progress an industry finally reaches a point where its growth continues to increase but at a decreasing rate, and so on into the period of stability where it becomes part of the economic and social life of man.

Merely to know that such growth is a possible fact is not enough. To make this knowledge really useful it is necessary to measure this growth. Before this can be done it is necessary to have a clear conception of what constitutes and influences this growth.

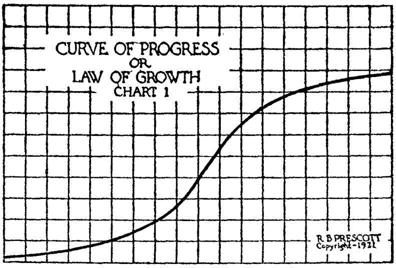
Every individual exerts some influence upon the growth of an industry. These influences vary in intensity and quality, from an extremely favorable attitude to one strongly unfavorable. The yearly summation of these favorable or unfavorable influences determines the progress of an industry. Some of these influences are more vital in shaping the course of the industry than others; some are so slight that they hardly make any impression at all. It is the combination of these many influences each year that finally determines whether or not the industry grows.

These influences may be grouped under two heads, "internal" and "external." The internal can be controlled to a large extent, and the external can be created by the proper action of the internal influences. If the internal influences are very strong, they naturally create more favorable external influences, sometimes called "good-will."

Strong internal influences are created by having a strong organization, good products, and sound policies. Of course there are many factors that enter into these broad divisions which permit of many combinations of favorable or unfavorable influences. One of the most common is the personality of the executives upon whose shoulders lies the responsibility for selecting the members of an organization, developing the product, and creating the policies under which the industry is operated.

In a large industry some companies make real progress while others remain stationary. The successful company is one in which internal influences have been combined, resulting in a strong organization with a concomitant creation of favorable external influences. The degree to which the favorable external influences are created depends entirely upon the extent to which the favorable internal influences dominate the combination.

If an organization has a good product that is properly manufactured, advertised, and sold, a demand will naturally develop for the product and good-will will be created in the minds of users. In order that an industry may make steady progress under our competitive system, it must continue to have strong internal influences which are constantly creating strong external influences; otherwise it would retrogress.



The result of the summation of these many influences is measured in the yearly volume of business transacted, whether it is in physical units or in value. The geographical expression of this growth is shown by the curve traced in Chart 1. This curve seems to be fundamental for all industries that are either directly or indirectly functions of population; *i. e.*, whose growth depends directly or indirectly upon the ability of the people to consume their products. Every country may have a different rate of growth, and so may every industry, because no two industries have the same combination of influences. They will trace the same type of curve, however, even though the rate of growth is different.

It seemed as though it might be possible to obtain a general equation by which one could express and measure this phenomenon of growth as shown in Chart 1. After I had experimented with several equations that would fit the conditions for part of the curve, the Gompertz curve[1] was suggested to me. I experimented with this curve, first with population and then with a number of products, with quite satisfactory results, which indicated that it might be possible to forecast the probable growth of an industry and, by so doing, the probable demand for the product. Of course it must be realized that even if this equation will forecast probable or normal demand for a product, the business cycle must be taken into account before the actual demand can be

[1] I am indebted to Professor Harry C. Carver, of the University of Michigan, for suggesting the Gompertz equation as a curve having the desired trace, and to Professor Henry L. Moore, of Columbia University, for further assistance in its use.

forecast for any particular year. I believe that this equation can be used to forecast the normal growth of an industry over a period of time, though the yearly functions may be above or below this curve. It is the average of these variations that determines the growth.

The equation[1] is as follows:

$$y = ab^{c^x}. \tag{1}$$

$$\text{Log}\, Y = \text{Log}\, A + c^x\, \text{Log}\, B. \tag{2}$$

Let now x become successively x_1, $x_1+1+\quad . \;. \;. \;\; +x_1+n-1$. Then taking the sums we get

$$\sum_{x}^{x+n-1} Y = nA(c^x + c^{x+1} + \quad . \;. \;. \quad + c^{x+n-1})B. \tag{3}$$

The series of c is in geometrical progression.

Such a series is:

$$S = \alpha + \alpha\beta + \alpha\beta^2 + \quad . \;. \;. \quad + \alpha\beta^{n-1}$$

$$\therefore \beta S = \alpha\beta + \alpha\beta^2 + \quad . \;. \;. \quad + \alpha\beta^{n-1} + \alpha\beta^n$$

$$\therefore S(1-\beta) = \alpha(1-\beta^n) \text{ and}$$

$$S = \alpha\frac{(1-\beta^n)}{(1-\beta)}.$$

Consequently the sum of the c series is

$$S = c^x\frac{(1-c^n)}{1-c} = c^x\frac{(c^n-1)}{(c-1)},$$

and we may write (3)

$$\sum_{x}^{x+n-1} Y = nA + c^x\frac{(c^n-1)}{(c-1)}B. \tag{4}$$

This equation (4) will enable us to find the constants in the formula.

There are three constants in the equation, and we therefore need to have three simultaneous equations. If we divide up our observations into three equal parts we have, using equation

$$\sum_{x}^{x+n-1} Y = nA + c^x\frac{(c^n-1)}{(c-1)}B \tag{4}$$

$$\sum_{x+n}^{x+2n-1} Y = nA + c^{x+n}\frac{(c^n-1)}{(c-1)}B \tag{5}$$

$$\sum_{x+2n}^{x+3n-1} Y = nA + c^{x+2n}\frac{(c^n-1)}{(c-1)}B.$$

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[1] As far as I have been able to learn, this equation has never been fitted to economic data before.

Differencing both sides of these equations, we get

$$\sum_{x+2n}^{x+3n-1} Y - \sum_{x+n}^{x+2n-1} Y = c^{x+n}\frac{(c^n-1)^2}{(c-1)}B$$

$$\sum_{x+n}^{x+2n-1} Y - \sum_{x}^{x+n-1} Y = c^{x}\ \frac{(c^n-1)^2}{(c-1)}B.$$

These two equations may be written

$$\Delta\sum_{x+n}^{x+2n-1} Y = c^{x+n}\frac{(c^n-1)^2}{(c-1)}B \tag{6}$$

$$\Delta\sum_{x}^{x+n-1} Y = c^{x}\ \frac{(c^n-1)^2}{(c-1)}B.$$

Now dividing both sides of the first equations in (6) by the corresponding side of the second equations in (6) we get

$$\frac{\Delta\sum_{x+\,n}^{x+2n-1} Y}{\Delta\sum_{x}^{x+n-1} Y} = c^n.$$

Take the logarithms of both sides

$$\log\Delta\sum_{x+n}^{x+2n-1} Y - \log\Delta\sum_{x}^{x+\text{n}-1} Y = n\log c. \tag{7}$$

Equation (7) enables us to compute at once the value of c. We may then find (b) from either of the equations in (6). Finally A may be obtained from (2).[1]

In studying the factors which influence the law of growth of populations or of an industry that is a direct function of population, motor vehicle registration data were fitted to the previously mentioned equation, as I was particularly interested in the automotive industry.

It was thought that if results obtained by fitting these data to the equation were reasonably satisfactory, it would create possibilities for reaching the solution of many problems that face the industry, the principal problem being to determine the number of motor vehicles that can be absorbed in the United States yearly.

The automotive industry is of comparatively recent origin; hence data for only a few years are available, and the results of the research probably cannot be considered to have the same degree of accuracy in measuring the law of growth, or in forecasting over as long a period, as they would have if data for an older and more firmly established industry, which has entered the period of stability, had been used. The results of the experiment may be seen in Chart 2 which shows the number of vehicles registered yearly, with the year 1921 as a forecast. The curve is extended to 1930 for the purpose of seeing how soon motor vehicle registrations will approximate the same rate of growth as population. It is not my intention that there should be considered seriously any forecast of more than a year or two, or perhaps three years beyond the data used, which in this case was up to 1920.

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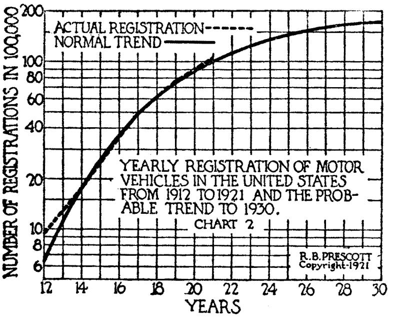
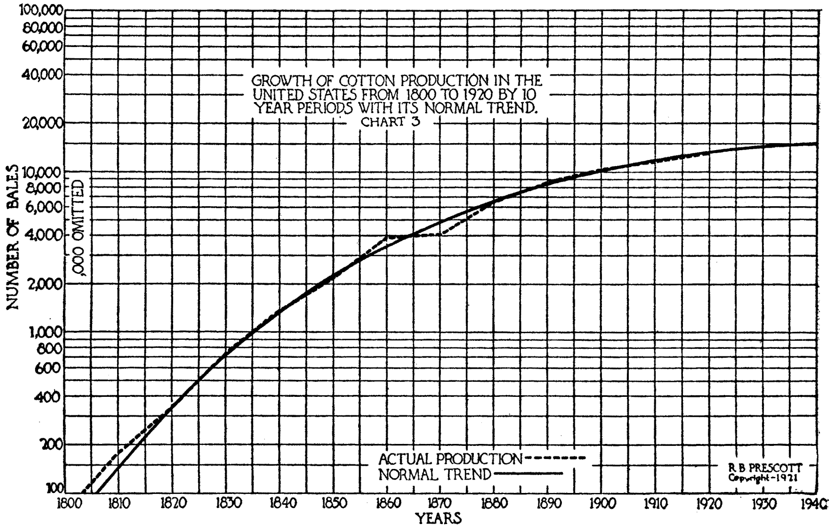
[1] The equation was first published in *Automotive Industries*, Nov. 17, 1921.



To show that with more extensive data it is possible to determine better the law of growth and to forecast more accurately for a longer period than with the data over a short period as in the case of the automotive industry, an older industry was used. For the experiment the total production of cotton was used for each tenth year beginning with 1820 and ending with 1890. The available data were then fitted to the above equation and the curve plotted as shown in Chart 3. The curve was then extended to 1920, a period of thirty years beyond which any data were assumed to have been available, with the pleasing results of only about a 2 per cent error n 1920. The forecasts for the three years were as follows:



	Actual	Graduated
1900	9,863,000	10,123,000
1910	11,600,000	11,608,000
1920	13,261,000	12,987,000

These results may be just a coincidence; but it hardly seems probable that three years, ten years apart, could be forecast as accurately and be merely a coincidence.

Many of the organizations in the industries that have kept any statistics have confined them almost entirely to their respective companies. That is all right as far as it goes, but it is only the beginning. Data showing only the yearly growth of an organization with respect to itself give little information as to what the real demand for the product is, or what percentage of the total business it is securing. An organization must know its progress with respect to the whole industry and what percentage of the total yearly business it has been getting over a period of years in order to obtain the proper perspective of its place in the industry. Such information will permit the executives of an organization to see the true position of the company and to determine its growth with respect to the whole industry.

To apply this equation to a single company would be just as dangerous as it would be for an insurance company to try to insure each individual without any knowledge of the law of probability. In an industry composed of a number of companies there is an opportunity to use the law of large numbers, which large number is the summation of their yearly volume of business. By use of these numbers an average can be forecast, and the probable error of variation and the percentage of the total business that a company has had over a period of time can be determined. On that basis the percentage of business that a company will secure for a year or two in advance can be forecast within probable limits of variation. This variation can no doubt be decreased if the demand for the product of any industry is adjusted to the business cycle.

By this method of forecasting the possible demand an industry can also determine the yearly probable demand for its product, and the various companies that constitute the industry can determine their respective positions. They should then confine their efforts to supplying that total, and should not over-expand, as has been the custom of the past. If this condition could be realized, it probably would eliminate some of the variation in the business cycle and make the probable error in forecasts much smaller.

It is hoped that large industries will realize that in forecasting the demand for a product for a whole industry there is a maximum that the country can consume yearly, and that as the price increases, the possible demand becomes more and more limited. It has been found that by dividing the sales of cars into price classes, it is possible to forecast the probable percentage of the total sales in each group. For example, the probable sales for 1921 in each price class were forecasted in February of 1921; at the end of the year the actual sales were determined and the following comparison was made:

	Under $1,000	$1,000–$1,999	$2,000–$2,999	$3,000–$3,999	$4,000 and over
Calculated percentage	75.0	19	4.0	1.0	1
Actual percentage	73.5	20	4.2	1.5	1

Professor H. L. Moore, of Columbia University, published in the March issue of this Journal an equation which probably will give a much more refined method of forecasting the number of cars that can be sold in each price class, or as a matter of fact, at any price. I am at present experimenting with this method as applied to automotive data. It is too early to say what the results will be.

In a period of time the production of every company in a large industry bears a certain relationship to the total production, and the yearly rates of its business compared to the total business of the industry over a certain period of time should give that company a clear idea of its relative position and the progress it has made.

Let us assume that a company has acquired the total production of its specific industry and has determined its yearly rate of business over a period of time, the more years the better. It then uses this growth curve or some other method to forecast the probable demand for the next year or so, or even three years in advance. The company knows its yearly percentage of business, from which it is possible to forecast the probable percentage it will acquire in the next year or so, the third year being used only in a general way as a possible tendency. In the automotive industry it is even possible to carry this further by using the car registrations in each geographical division to forecast the probable sales of cars by makes or price classes in each of the nine geographical divisions used in the United States census chart. By adding the demand for any make of car in all the geographical divisions, it should check very closely with the demand determined from the production figures as outlined above.

With the potential demand determined, it is possible for a company to lay out its sales quotas—production schedules, purchases of materials, and financial arrangements and budgets—for each department for a year in advance and to adjust them each quarter according to the business cycle.

Manufacturers who employ this method or a similar one certainly will be in a much stronger position than manufacturers who continue to use the present inefficient methods. Facts show that no established company can acquire a great increase in its yearly volume except under the following conditions: (1) Introduction of a far superior product; (2) considerable reduction in price of an old established product.

A company may acquire a steady yearly increase in business by continually employing better methods than its competitors, or in other words, creating more favorable influences, both internal and external.

When scientific methods of forecasting future demands for products are generally employed in the basic industries, probably the variation in the business cycle will be considerably less. This would partially eliminate the sharp periods of inflation and depression and would tend to keep business on a more even basis than at present.